31. *The* Howgill Fells *and their* Topography.

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[Plates XXVIII–XXXI.]

The Howgill Fells form a well-defined geographical unit. They occur as an upland tract of roughly triangular form, the angles being blunted. The northern side of the triangle is defined by the valley in which the village of Ravenstonedale lies. It extends for 8 miles measured in a straight line, in a direction a little north of west, from a point 2 miles south-east of that village to the village of Tebay. This valley was originally watered by the streams of the Lune drainage, although (owing to subsequent diversion) the waters at its eastern end now find their way into the Eden.

At Tebay the main waters of the Lune flow southwards, and this part of the course of the Lune forms the western side of the triangle for a distance of 8 miles to a point a little west of the town of Sedbergh. The trend of this side is about 5° east of south.

The third and longest side is curved, and measured along the straight is about 9 miles long. At the north-eastern end it is defined by the Dent Fault and its parallel fractures as far as Rawthey Bridge, after which it follows the line of the Rawthey to the southern end of the second side immediately west of Sedbergh.

Along these lines a continuous depression separates the Howgill Fells from the adjoining heights on the west, north, and south-east. The bottom of this depression along the major portion of its length is less than 600 feet above sea-level, and only at the col connecting it with the limestone country to the east of the Dent Fault does it ever rise beyond the 900-foot level. Before the diversion mentioned above the whole of the depression along this boundary was drained by waters carried to the Lune by way of Ravenstonedale and the main valley on the north and west, and by the Rawthey on the south-east.

Geologically the Howgill tract is almost as well-defined as it is geographically. On the west side, it is true, the strata extend across the Lune from the Howgill Fells to the fells west of that river, and the division is only physiographical; but on the north and south-east sides it is practically defined by the line of junction between the Silurian and the Carboniferous rocks, though some of the older rocks extend across the Rawthey to form the flanks of Baugh Fell beyond the limits of the Howgill Fells.

The Howgill Fells, then, consist essentially of Silurian rocks (with inconsiderable patches of Ordovician strata in the neighbourhood of Rawthey Bridge). These rocks are referable to the divisions known as Stockdale Shales, Coniston Flags, Coniston Grits, and

Bannisdale Slates, but the main mass is composed of the slates of the two last-named divisions, which, notwithstanding their different names, have much in common; and, as will be shown later, the uniformity of character of the rocks is of great importance in determining the physiographical features of the fells.

The general relationship of the Howgill Fells to the surrounding tracts and the cause of the severance of these Fells from those to the west of the 'gorge' of the Lune have been considered by one of us elsewhere,[1] and need not here be discussed. From our present point of view the important point is that the Fells constitute a monoclinal block, with its dip-slope on the north and its scarp facing south, though both dip-slope and scarp are shortened at the eastern end owing to the trend of the Dent Fault.

Accordingly, could we but fill in the hollow spaces produced by valley-erosion, we should find the Fells presenting a 'desk'-structure, with the gentle long slope to the north and the short sharp drop to the south. The summit-ridge ranges east and west at a height of about 2000 feet quite close to the southern edge. There is evidence that at one time the watershedding ridge lay much nearer the southern and farther from the northern margin of the tract. (See Pl. XXIX.)

If the junction of the Carboniferous and Silurian rocks were continued over the summits of the Howgill Fells, where the former have now been removed, it would appear as a gently sloping plane not far above the tops of those hills. At present, the lowest Carboniferous rocks occupy the Ravenstonedale Valley north of the Howgills; they are seen to rest on the northward continuation of the hills themselves, and have a dip which is sufficient to carry them over all the hills. The base would, if continued along the present dip-plane, carry them some hundreds of feet above the fell-tops. The sudden increase of slope of the surface, however, as it approaches the Carboniferous rocks seems to indicate that there was there a monoclinal flexure, and that the dip became much higher to the north: hence it is probable that the present surface, if the valleys were filled in, would coincide fairly closely with the original base of the Carboniferous strata.

South of the Fells a continuation of this dip would carry the Carboniferous some hundreds of feet above the River Rawthey; whereas, in fact, for a distance of more than 3 miles the 'Basement Carboniferous Conglomerate' actually occupies the valley-bottom in the neighbourhood of Sedbergh, where it is let down by a great fault. The steep southern face of the Howgill Fells is determined by this fault, which trends south of east to west of north. But the fault is not simple: the Geological Survey map shows three faults parallel to that which brings in the Carboniferous of the Rawthey Valley against the Silurian of the fells. These are probably step-faults, and the northernmost of them which occurs behind Winder Crook and the Knott is no doubt responsible for the shelf

[1] Quart. Journ. Geol. Soc. vol. lxii (1906) pp. xcvi–xcix.

of dip-slope which is preserved upon these hills at a much lower level than that beyond the summit-ridge to the north.

Another fracture apparently occurs north of the main watershed, crossing the district from west to east from the Carling Gill Valley to Ellergill Sike, forming a step in the dip-slope, and by its shattering determining a row of cols more or less parallel to the main watershed.

The shatter-belt[1] of this fault is very wide, and is marked along its course by hæmatite staining, probably introduced from above when the basement-conglomerate covered the tract.

The section drawn from the Calf to the river Lune along the hill-tops west of Bowderdale (Pl. XXXI, fig. 2) shows the character of the displacement and the general characteristics of the old Pre-Carboniferous dip-surface in this district.

The movement which caused the present elevation of the Howgill Fells, the nature and age of which have been referred to by one of us elsewhere,[2] was apparently so widespread that it caused but little warping of the northern Carboniferous dip-slope just discussed, and the consequent displacement of the Silurian platform may here be neglected. As the basal Carboniferous rocks were removed, the bared Silurian rocks must have appeared in the form of the monoclinal block in which we now find them.

On whatever rocks the rivers developed upon the Howgill tract were initiated, the retardation of erosion when Silurian rocks were encountered would be so considerable that the streams occupying the thalweg of the waters in the Ravenstonedale Valley, along the soft rocks of the basal Carboniferous, must have lowered that tract considerably before the Howgill streams could accomplish much erosion.

Similarly the Rawthey was eroding in weak rocks, and the Lune south of Tebay perhaps keeping open its course along a line of weakness during uplift. Consequently the triangular stretch of what is now low ground surrounding the Howgill Fells was lowered, leaving the upland monocline in its midst. Upon this central block of the Howgill Fells, the drainage-lines were therefore determined by (*a*) the ridge between dip-slope and fault-scarp as watershed, and (*b*) the three depressions of Ravenstonedale, the Lune below Tebay, and the Rawthey Valley and its northern feeder Sally Beck, which extends to a col looking over to Ravenstonedale.

A series of long streams were developed on the dip-slope and flowed northwards. Of these, Tebay Gill and Ellergill and some

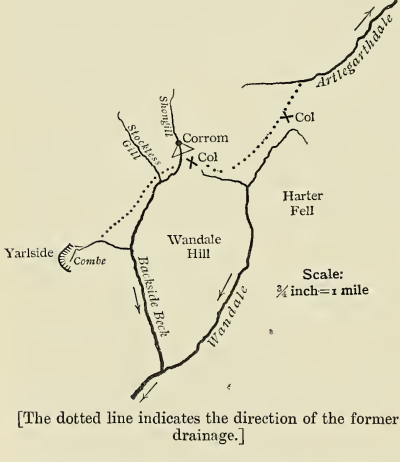
[1] I have elsewhere described a series of shatter-belts as occurring among the Lower Palæozoic rocks of Lakeland, along tear-faults; but the term was not then defined, and there is no reason to confine it to the shattered tracts along tear-faults. I may define a shatter-belt as 'a belt along which the rocks have been shattered by movement into large and small fragments, the rocks on either side not necessarily being permanently displaced, although they are frequently so displaced.'—*J. E. M.*

[2] Quart. Journ. Geol. Soc. vol. lxii (1906) pp. xcvi–xcix.

minor streams rose somewhat to the north of the main watershedding line, but the streams of Uldale, Langdale, Bowderdale, and Artlegarthdale all rose upon that line. Owing to the gentleness of the slope all these streams had low grades. South of the main watershedding line, on the short scarp-slope, brief steep-graded streams flowed southwards to the Rawthey, namely, Hobdale, Cautley, Backside, and Wandale Becks; and the steep side towards the Lune south of Tebay was also drained by the short and steep Carling Gill and Blands Gill and their tributaries.

The early dissection of the monoclinal block-tract was produced by these streams and their tributaries; but, as the northward flowing streams are near together, their tributaries are unimportant, and hence the ancient surface of the Silurian platform is preserved on the divides between the streams with but little change.

Fig. 1.—*Plan illustrating the drainage of Backside and Wandale Becks and Artlegarthdale.*



[The dotted line indicates the direction of the former drainage.]

Modifications of the drainage are due to the tendency of the short swift streams flowing to the Lune south of Tebay and to the Rawthey on the south of the fells to cut back into the watershed, and to capture the head waters of the northward-flowing streams.

Beginning at the north-west, and working southwards and then eastwards, we find that the first important captures are made by Carling Gill. The head of Tebay Gill remains intact; but that of Ellergill next to the east has been cut off, and a col connects it with Carling Gill. The most striking capture, however, by Carling Gill is that of the Black Force stream and of the head of Uldale. Farther south another of the westward-flowing streams, Longrigg Beck, has cut off the heads of two of the tributary streams of another Ellergill, which flows to the Lune. A feeder of Longrigg Beck has also beheaded West Grain Beck, a tributary of the northward-flowing Langdale Beck, and has so produced the col known as Wind Scarth Wyke.

None of these captures, save that of Great Ulgill and the Black Force (Little Ulgill) streams by Carling Gill, are of any serious importance.

In the south the southward-flowing streams have not yet cut through the western part of the watershed. In the east, however, the monoclinal ridge has been much cut into, and very important captures have resulted. Of these the most pronounced is that made by the Cautley stream, and the robbery of the waters that once flowed into Artlegarthdale by Backside and Wandale Becks (see fig. 1, p. 590).

The steeper grades of the capturing streams would, no doubt, have caused all these captures to occur in time. As it is, there is evidence of the acceleration of some by glacial agency, which renders them of particular interest, and the whole evidence will be considered when the glaciation is described.

The pre-Glacial Condition of the Howgill Tract.

The erosion by the various streams had already dissected the monoclinal highland in pre-Glacial times. As before seen, the conditions produced north of the watershed were such that the streams left ridges with summits sloping gradually down northwards from the watershed and with few definite minor summits along the ridges. On the south side, where conditions were much more complex, actual hill-summits are found: such are Arant Haw, Calders, Yarlside, Wandale Head, Harter Fell, and others.

A great feature of topographic interest in the glaciology of the Howgill District is, that while some of the valleys are clearly much ice-worn, others bear no sign of glacial erosion, and consequently the effects of stream- and of ice-erosion can be compared or contrasted within a limited space.

The study of valleys not appreciably affected by ice gives an idea of the effects produced in this district by stream-erosion. The best examples of such valleys are occupied by the feeders of Bramrigg Beck. These valleys show well-marked V-shaped outlines with slightly convex slopes, culminating at the head in slightly rounded ridges and summits. At present, their slopes are entirely clothed with vegetation, as also are the summits, and this tract presents outlines like those figured by Prof. W. M. Davis in the Scottish Geographical Magazine for 1906, in fig. 1 of his paper on 'The Sculpture of Mountains by Glaciers.'

No cliffs with exposed rock and no abrupt changes of slope are seen in these and similar valleys of the district. There is no doubt that their monotony of outline is due to the similarity of the behaviour of the component rocks of the hills as regards weathering. We have already noted that the Fells are chiefly composed of Coniston Flags and Grits and of Bannisdale Slates. These rocks are greywacké grits and mudstones, which are usually well jointed and break into small pieces. Moreover, owing to the nature of the

binding material between the grains, these grains become separated in the course of weathering; and grits, slates, and mudstones all behave similarly, giving rise to a thin soil on which vegetation flourishes and prevents the downward carriage of fragments by surface-water runnels. The material is being gradually removed by soil-creep among the vegetation and superficial detritus.[1] It is doubtful whether in times immediately preceding the Glacial Period any rock was exposed, save only in the stream-courses; and the evidence points to the production of the present rock-exposures on the hillsides in three ways:—(1) by truncation of spurs by ice; (2) by corrie-glacier erosion[2] in the combes; and (3) by the post-Glacial erosion of captured streams adapting themselves to their grades.

Glaciation of the Fells.

Our study of the ice-work of the Howgill Fells area leads us to adopt generally the views of the late Mr. J. G. Goodchild, as described in the letter-press and indicated on the map accompanying his paper.[3] We regard the Howgill Fells as an independent centre of glaciation, the ice-field of which covered nearly the whole area and had an ice-shed agreeing with the present watershed. From this the ice flowed down the three slopes of the triangle, northwards to the Ravenstonedale depression, westwards to the Lune, and southwards to the Rawthey Valley. This ice-sheet united in the north with that which came from the Lake District to pass eastwards over Stainmoor; on the west with that which came over Shap Fells; and on the south with that which, originating on the uplands of Baugh Fell and Wild Boar Fell, extended thence down the valley of the Rawthey.

The distribution of the drifts suggests that the ice filling the three depressions acted as follows:—In the north, the Howgill ice in the Ravenstonedale depression was, save at the western end, able to push back that of the Lake District to the north of that depression. On the west, the Lune ice held its course from Tebay as far south as Carling Gill. It was then pushed aside by the Howgill ice and driven through the depression which the railway follows from Lowgill to Grayrigg towards the Kent Valley. On the south, the ice of Wild Boar and Baugh Fells kept the local ice from the short scarp-face from getting a footing in the Rawthey valley, diverting it to the westward, and in one place to the north-eastward. Reasons for these views will be stated subsequently.

[1] See J. E. Marr, 'The Origin of Moels & their Subsequent Dissection, Geogr. Journ. vol. xvii (1901) p. 63; also G. Götzinger, 'Beiträge zur Entstehung der Bergrückenformen' Penck's Geographische Abhandlungen, vol. ix (1907) pt. 1.

[2] After reading Willard D. Johnson's paper in the 'Journal of Geology' (Chicago) vol. xii (1904) p. 569, we would go further and speak of Bergschrund erosion.

[3] 'The Glacial Phenomena of the Eden Valley & the Western Part of the Yorkshire Dale District' Quart. Journ. Geol. Soc. vol. xxxi (1875) p. 55 & pl. ii.

(A) Glaciation of the Lowland Tracts around the Howgill Triangle.

(1) The Ravenstonedale Lowland.—Examination of Goodchild's map in the paper cited shows the line of the approximate southern limit of the Shap Granite boulders and the eastward trend of the ice which carried them. There is little doubt that these boulders were kept from passing southwards by the Howgill ice which was emerging from Langdale and the valleys on the east, which, as far as Artlegarthdale, are filled with drift charged with Howgill boulders. But Tebay Gill is filled to the head with drift from the north, containing boulders of Carboniferous rock, Shap apophyses, and occasional boulders of the parent Shap Granite. (One actual fragment of the last-named, an inch and a half in diameter, was taken from a clay-bank near the head of Tebay Gill; and a large mass, 6 feet in diameter, may be seen close to the mica-trap, half a mile east of Tebay railway-station, in the stream, and many others of less notable size abound in the same neighbourhood.) A thermally metamorphosed mass of Yarlside rhyolite was also observed. Ellergill has Carboniferous boulders a long way from its mouth, and possibly all the way to its head. It will be noticed that both Ellergill and Tebay Gill are short and comparatively unimportant valleys, which start far north of the main water-shedding line of the Fells.

The ice which filled the Ravenstonedale depression was responsible for the formation of the gorge through which the Smardale stream flows: the Smardale Gorge is, in fact, a marginal overflow. (In a paper published in the Proceedings of the Geologists' Association, vol. xx, 1907, p. 147, one of us did not accept the idea of a marginal overflow from ice, but during a subsequent visit was convinced by Prof. W. M. Davis.) A similar overflow occurred in a tributary valley from Sunbiggin Tarn, and another to the east of Ashfell Edge; but these have not produced any marked deflection of the drainage. We are not, however, concerned with marginal overflows in the present paper.

(2) The Lune-Gorge Lowland.—That ice from the Lake District flowed some way down the Lune gorge is shown by the fact that boulders of Shap Granite and apophyses have been noted by Prof. Hughes at the foot of Carling Gill, and boulders of the apophyses have been found by us as far as Lincoln's Inn Bridge. A boulder of the granite was also noted at the bridge, but may have been carried down by the stream. The scarcity of these boulders shows, however, that the Lune ice was diverted south-westwards, as maintained by Mr. Dakyns and in the Geological Survey Memoir.[1] That the ice coming from the Howgill Fells (especially through the

[1] 'The Geology of the Country around Kendal, Sedbergh, Bowness, & Tebay' Mem. Geol. Surv. 1888, p. 49.

Rawthey Valley) was more powerful than the ice coming down the gorge, is indicated by the direction of the drumlins in the fork where the two valleys meet. The Howgill and Rawthey ice there pushes its drumlins well out into the gorge. The Lune gorge is well glaciated: it is a marked U-shaped valley with well-truncated spurs, which give much of its sides a rocky character. On the west side is a hanging valley forming the northern half of Great Combe, and the rest of that combe was apparently enlarged by a corrie-glacier. The truncated spurs may be well seen, from viewpoints about Tebay, or between that village and Low Borrow Bridge; and below them the valley has been to some extent deepened by ice. Subsequently, however, that part of the valley was filled with Boulder Clay which is now being excavated by the river, but still forms a marked terrace on each side of the valley, where the flatter lower portions of the old catenary drift-slopes remain undenuded. Towards Sedbergh the Lune Valley drift is less regularly arranged than it is to the north of Lowgill: for this part of the valley was the dumping-ground for terminal morainic material.

(3) The Rawthey Lowland.—The Rawthey Valley is wide and, on the whole, flat-floored. The north side, forming the scarp-face of the Howgills, is characterized by admirable truncated spurs on all the hills between the Lune and Rawthey Bridge. These, when viewed from near Sedbergh railway-station, are well seen on Winder and Crook, where the change of slope and the rocky character of the spurs is clearly exhibited. But, although these spurs afford testimony of the widening of the valley by ice, there is little evidence of serious overdeepening by the same agency. Much drift, however, still lies in the valley concealing a great portion of the floor, and this may, to some extent, mask overdeepening.

(B) Glaciation of the Valleys of the Howgill Highland.

It will be convenient to treat these valleys in order, according as their waters flow to the Lune Gorge, the Rawthey or the Ravenstonedale Lowland. We will begin with the valleys tributary to the Lune Gorge.

Two small valleys occur on the east side of the Lune, between Tebay railway-station and Carling Gill. They do not appear to have been glaciated, but are filled with deltoid masses of drift (save only where subsequently cleared out by post-Glacial stream-erosion); and the drift runs continuously with that of the Lune-Valley terrace, forming the upper part of its catenary slope. This drift appears to have been deposited by Lune ice moving transversely and at right angles to these valleys.

Deltoid masses of drift occupy the bottoms of many of the minor valleys. The apex of the delta is towards the valley-head, and the drift slopes with a fairly uniform grade towards the foot—the surface being nearly plane, or forming a slight catenary in cross-

section. The margins of the drift at the valley-sides are usually well defined.

The deltoid drift-masses seem to occur when the ice has moved up-valley or transversely thereto, or has flowed over a col into another valley, thus suggesting that they are due to the melting of inert ice.

Going southwards, we now arrive at the important valley of Carling Gill, the waters of which rise on Fell Head. For more than a mile up from its junction with the Lune, the Carling Gill Valley is wide and U-shaped with truncated spurs, and shows the glacial scooping of which we speak as 'conchoidal' on the concave sides of its bends.[1] One of the best of these scoops is seen on the southern bank of the stream west of Green Knott Gill.

There is much drift on the valley-floor. A deltoid mass of drift cut through by Grains Gill and the lower part of Weasel Gill contains Carboniferous boulders and is traceable up to, and beyond the col which marks the beheading of Ellergill, into the valley of the latter stream. It is clear that the ice which, as before stated, filled Ellergill from the north also gave rise to this delta, which must have been left by a tongue of northern ice coming through the col.

The top of the U-shaped part of Carling Gill is at a point south of Uldale Head. Here Carling Gill once had three heads. That on the north from Uldale Head (Great Knott Gill) is now marked by a U-shaped valley, with a combe at the head and a deltoid mass of drift below. Small Gill on the south side is also a well glaciated U-shaped valley with much drift, and ice may have traversed the pass at its head to Fair Mile Beck on the south. Traces of a third head are also seen in the slightly modified slopes west of Black Force; but the shape of the ground shows that there ice-erosion has had but little effect. It is into this central head that the streams which have been diverted into Carling Gill flow.

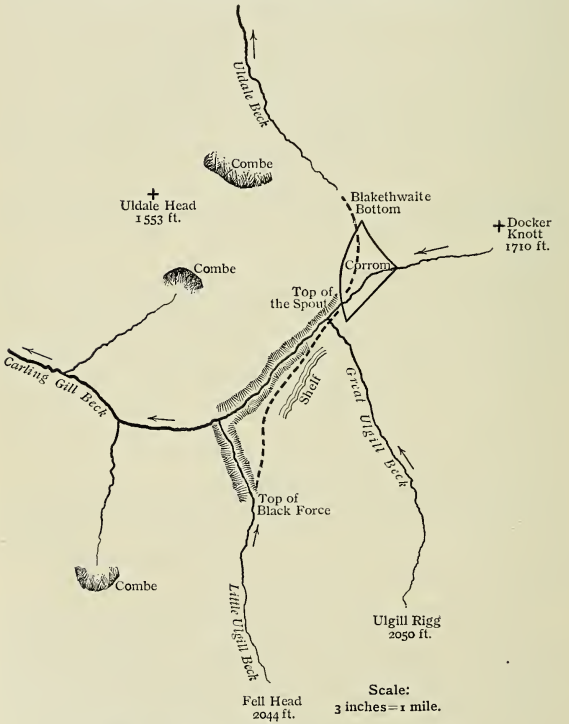
Dr. Strahan detected the diversion of the old Uldale waters into Carling Gill, but does not notice the deflection of those of the Little Ulgill Beck Valley which forms Black Force. In the Geological Survey Memoir ('The Geology of the Country around Kendal, Sedbergh, &c.' 1888, pp. 45–46) he writes

'In the head of Uldale a remarkable instance of the intersection and tapping of the water of one dale through the eating back of the head of another has been observed. It will be seen by the distribution of the Drift that the Uldale Valley starts under Wind Scarth and crosses the County Boundary. The hills forming the west side of the valley, however, are breached at the County Boundary by a deep and rocky but narrow ravine, by which the water collected under Wind Scarth finds its way direct to the Lune at Carlingill, instead of following the Uldale Valley to Gaisgill. There can be little doubt that originally Uldale formed a continuous line of drainage up to the foot of Wind

[1] This term is used, because the ice gives rise to concave scoops recalling the appearance of the inner side of the valve of a clam-shell.

Scarth, and that the diversion of its head waters has been due to the cutting-back action of the head waters of the Carling Gill. A small dam would even now be sufficient to turn the waters back to their old course. The date at which the change took place is uncertain. The rocky ravine referred to is altogether devoid of Drift, but this may merely be the result of the rapid erosion that is taking place, and not necessarily a proof that the ravine is of post-Glacial origin. It seems hardly likely that so deep a cut can have been made in solid rock within the post-Glacial period.'

Fig. 2.—*The Carling Gill-Uldale diversions.*



[The broken line indicates the former drainage.]

The accompanying diagrammatic plan (fig. 2) illustrates the physical features here and our explanation of them.

There is no doubt that in pre-Glacial times the Carling Gill stream was almost ready to behead Little Ulgill Beck below the site of what is now Black Force. The slopes on the south side of Green Knott (a shoulder of Uldale Head) and on the opposite side of Carling Gill indicate the existence of a curved valley-head (the middle head above described), which cannot have been separated from Little Ulgill Beck Valley by more than a few score yards, and it was much more deeply cut than was the latter valley. The valley above Black Force is well glaciated, U-shaped, and with much drift which is now spilt over Carling Gill north-east of Black Force, owing to the subsequent capture of Little Ulgill Beck by Carling Gill. The evidence is, on the whole, in favour of the ice in Little Ulgill widening that valley to a sufficient degree to cut through the ridge between it and the middle head of Carling Gill, at which time ice- and moraine-matter was spilt over into the deeper Carling Gill. After this occurrence, and after the recession of the ice, the waters of Little Ulgill Beck, following the ice-course, have cut out the water-carved gorge of Black Force, which is 590 feet high from top to base, the old valley being one of the most striking hanging valleys in the North of England, especially as seen from Green Knott.

After this capture, the further capture of the Great Ulgill Beck discussed by Dr. Strahan was a small matter. The old beheaded valley would be dry as far down as the point of incoming of the next tributary, the waters of which would therefore tend to build out a delta across the main valley. This delta would grow to a height sufficient to direct the waters along the dry valley to a point where they could get across to the Carling Gill drainage. This has been done, and, owing to the increased grade, a deep cut has been made here also (at the Spout), though not with so marked a waterfall as at Black Force. It must be noted that this cut is partly in the old course of the curved middle head of Carling Gill, and that, therefore, the amount of post-Glacial erosion is not so great as Dr. Strahan suggested. The cañon-like character of the gorge, with its overlapping spurs and rocky precipices, indicates its post-Glacial formation. Traces of an old shelf on the left bank of the gorge mark the old east side of the valley-floor of Little Ulgill.

The diversion by delta-growth described above is actually seen in the process of diverting the next tributary down-stream into Carling Gill at Blakethwaite Bottom, and in a few years will probably be complete. At the time of our visit, the stream from Docker Knott was flowing over the south side of the delta into Carling Gill; but a dry channel in the delta-material, northwards into Uldale, may in time of flood take back the bulk of the waters in that direction, although of course the growth of the delta will eventually send the stream always the other way and a further stretch of Uldale will be permanently dry, and so prepare the way for another growth of delta by a tributary farther down stream, and yet other captures of the Uldale tributaries by Carling Gill. This

successive diversion by delta-growth of the downward tributaries of beheaded streams (however beheaded) must be a common feature, and we shall deal with another case in our district.

Cases of these delta-watersheds are described under the name of 'corroms' by Prof. P. F. Kendall & Mr. E. B. Bailey in their account of 'The Glaciation of East Lothian South of the Garleton Hills.'[1]

Fig. 3.—*The corrom: Blakethwaite Bottom, looking east.*

[The stream to the south of the corrom flows into the Spout.]

The old head of the valley below Ulgill Rigg is well glaciated, there being a Glacial combe there. Some of the ice possibly went over the col between Bleagill Head and Taffergill into the combe at the head of Churn Gill; but the main part went down the old Uldale Valley, though apparently it produced but little erosive effect, except in the combe at its head, depositing, however, a considerable amount of drift in the valley.

The lower part of Uldale, discharging northwards, will be described in its proper place.

South of Carling Gill is Fair Mile Beck, rising in two tributaries on the west side of Fell Head. The valley is a U-shaped valley, and its tributaries are also U-shaped, a small corrie-moraine occurring at the base of a small combe at the head

[1] Trans. Roy. Soc. Edin. vol. xlvi (1907–1908) p. 25.

of the southern tributary. Drift occurs on the col between the northern tributary and the Black Force valley, where, as already stated, a tongue of ice probably went over into the valley from Fair Mile Beck.

Proceeding southwards, we come to Ellergill (which must not be confused with the two valleys of the same name to the east of Tebay). It is a U-shaped valley, with much drift filling the floor. The disposition of this drift indicates that a lobe of ice came over the col north of Brown Moor (produced by the beheading of this Ellergill by Longrigg Gill), hence the U-shaped excavation of this comparatively short valley. Half a mile below the col, the occurrence of Lune Valley drift with Shap Granite apophyses, at a height of over 800 feet, shows that the Lune ice came over Whin End into Ellergill.

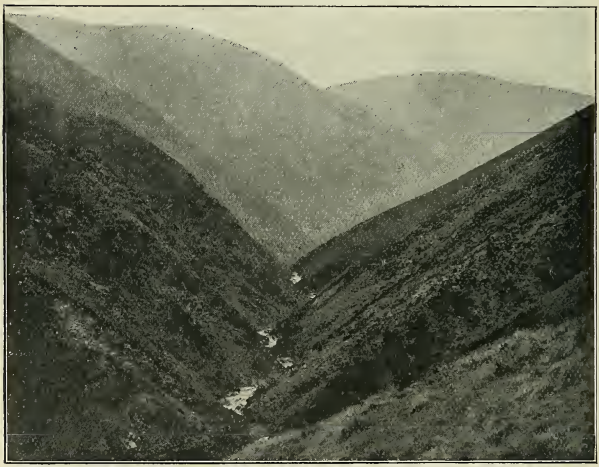
The next stream to the south is important. It is named Blands Gill on the 1-inch, and Chapel Gill on the 6-inch Ordnance Survey map. It has several feeders: the most important of these is Longrigg Beck, which rises on the south side of Ulgill Rigg, with a branch from Wind Scarth Wyke (which has beheaded a tributary of the north-flowing Langdale Beck). The head of Longrigg Beck is marked by a combe, and the valley is no doubt widened by ice, being U-shaped from the start. About a mile from its head it receives Longrigg Gill, which rises in a rocky combe on Fell Head, and flows through a markedly U-shaped valley that hangs some way below the combe. This hanging head of Longrigg Gill was probably at one time the head of the Ellergill valley, but was beheaded by the cutting through of a former ridge between Brown Moor and Longrigg in pre-Glacial times. The valley below this junction of the Beck and Gill is floored with drift. It retains its U-shaped outline and cross-section down to the low ground of the Lune Valley. A third of a mile below the confluence of Longrigg Gill, another stream (Calf Gill) joins Longrigg Beck, flowing from the east and rising on the highest plateau of the Howgill Fells. The Calf, from which the beck takes its name, is the summit of this plateau, and rises 2220 feet above sea-level. This valley has also suffered much from Glacial erosion, is again markedly U-shaped, and starts in a fine combe with morainic material at its mouth, just beneath the Calf.

On the west side of Longrigg Beck, opposite the entrance of Calf Gill, is a rocky hill, Castley Knotts, which, since we find moraines of drift sweeping in drumlins round its southern face, and crossing Longrigg Beck at a height of about 890 feet, was probably at one time completely overridden by Lune Valley ice. On the east side of the beck, 200 yards above the entrance of Bramrigg Beck, the stream has cut a fine section in the drift. This section shows about 20 feet of local stratified drift containing no foreign boulders,

resting upon 40 feet of stiff unstratified Lune Valley drift, with boulders of Shap apophyses, Carboniferous Limestone, and basement Carboniferous conglomerate: similar drift is seen in a section made by Bramrigg Beck, a few yards from its entrance into Longrigg Beck, and above a waterfall.

Bramrigg Beck comes in also from the east. This beck rises in a slight combe between Bramrigg Top and Calders, about a sixth of a mile south of the source of Calf Beck; but the valley is essentially waterworn. As far as the influx of the unnamed stream from Rowntree Grains it is typically V-shaped. The two

Fig. 4.—*A V-shaped valley near Arant Haw, looking towards the head.*



stream-heads of the tributary from Rowntree Grains have no combes, and are also strictly V-shaped. They furnish admirable examples of the outlines of valleys which have not been affected by ice-erosion: doubtless ice formed in them, but was not effective for erosion. Below the junction of the two forks, the V-shaped cross-section is slightly modified by a conchoidal scoop on the concave south side of the valley. Below the junction of this valley with Bramrigg, the latter becomes more powerfully affected by ice, and is intermediate between a typically V-shaped waterworn valley, and one of U-shape modified in a high degree by ice. It has a truncated spur on its southern side.

Two-thirds of a mile below the junction of the nameless tributary,

Swarth Greaves Beck enters Bramrigg Beck from the south-east. It rises on the slopes of Arant Haw, and like the last tributary is curved with the concave side to the south. It is very slightly modified by ice-erosion in its upper part, being essentially V-shaped, but has a conchoidal glacial scoop on the concave side lower down. As seen from Fell Head, the conchoidal scoops in these valleys show up well: the south-western sides of the ridges and their summits being convex, and the north-eastern sides concave.

Bramrigg Beck Valley was deepened by ice to a greater extent than that of Swarth Greaves Beck. Accordingly we find the latter valley hanging slightly, and a rocky gorge with a waterfall at its head is developed, owing to the subsequent tendency to adjustment of grade. The same features are noticeable in Bramrigg Beck itself a few hundred yards lower down, where a small gorge and waterfall mark the greater deepening by ice-erosion of Longrigg Beck Valley.

Over a mile south of Blands Gill is Crosdale Beck, rising on the south-western side of Arant Haw. The valley is emphatically straight and U-shaped, with truncated spurs on both sides. It has a straight course of 2 miles to its junction with the Lune. A tributary from the north (Combe Gill), rising in a combe, is also U-shaped. A deltoid mass of drift occurs near the head of Crosdale Beck.

This is the last stream that flows directly into the Lune, for the next stream in order enters the Rawthey.

Before leaving these streams, it should be noticed that, although they are clearing out the low-level drift of the Lune Valley in the lower part of their courses, they elsewhere flow in series of cascades over solid rock and are engaged in grading their beds to normal courses after the disturbance produced by the Glacial widening and over-deepening of the Lune Valley.

We now pass to the consideration of those valleys, the streams of which are tributary to the Rawthey, and shall take them in order from west to east.

The first stream, Settle Beck Gill, rises on the dip-shelf between Winder and Crook, and from its source falls steeply southwards, there being a difference in level of about 1000 feet in the mile between the source and the point where it reaches the low ground of the Rawthey Valley. It has been filled to a great depth with a deltoid mass of stiff drift containing well-glaciated boulders: the upper surface of this mass slopes almost uniformly downwards until near the Rawthey, where it joins the drift of the Rawthey Valley with a diminished slope. The stream is now clearing out the drift, as described in the Geological Survey Memoir, and is cutting between the drift and the solid rock, leaving a wide shelf of drift on the western side. The boulders in the higher parts are of local origin; but at a height of 800 feet above sea-level, and over 400 feet above the Rawthey at the junction of Little Gill, Carboniferous boulders occur, showing that the Rawthey ice rose

at least as high as this. The phenomena developed here are in part like those of the two gills north of Blease Fell, south of Tebay, where the ice was also moving at right angles to the tributary valleys.

Similar features are seen in the next valley to the east, Ash Beck Gill, which rises on the south-east side of Arant Haw and runs southwards to the Rawthey between Crook and Sickers Fell. They are seen also on a smaller scale in Little Ash Beck, between Sickers Fell and Knott. The appearance suggests that a tongue of ice flowed from the next valley to the east (Hobdale Beck), over a col behind and north of Sickers Fell, to the head of Ash Beck Gill, and thence over a col behind Crook to Settle Beck Gill. Hence Crook and Sickers Fell may have stood out as 'nunataks' between this ice and that of the Rawthey, though it is more than probable that at the time of maximum glaciation the confluent ice-masses also covered the fell-tops mentioned. Another tongue from the Hobdale Valley seems to have flowed through the col between Sickers Fell and Knott into Little Ash Beck.

It is very doubtful whether any ice-erosion occurs either in the Settle Beck or in the Ash Beck valleys, owing to the passage of ice at right angles. Appearances indicate that, if the drift were cleared away from them, they would show V-shaped cross-sections.

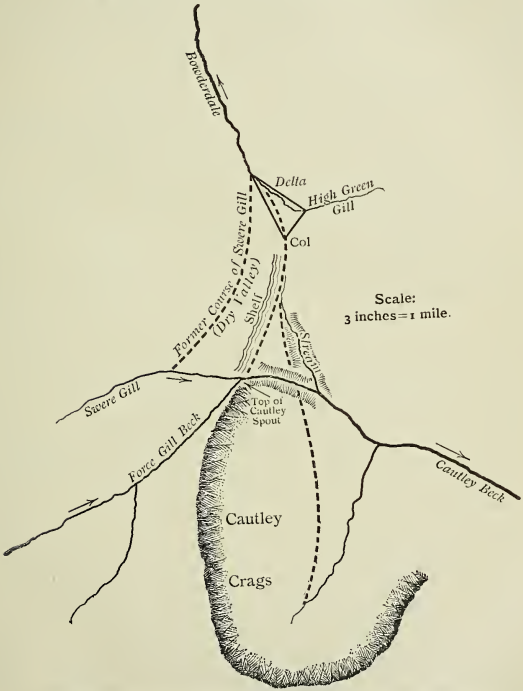
The Hobdale valley is of greater size than those last mentioned. Hobdale Beck rises in a combe below Calders (2200 feet) and flows southwards through a U-shaped valley with the truncated wrecks of overlapping spurs. It has a curved course with a concavity to the west where, below Hobdale Scar, there is a Glacial scoop to which the scar is due. Below this, the ice-tongue already mentioned crossed behind Sickers Fell and between Sickers Fell and Knott. About a mile below its source Hobdale Gill receives Grimes Gill, the source of which is not far from that of Hobdale Gill. It flows down the east side of Middle Tongue with a concavity on the east. In the upper part of Grimes Gill there is but little sign of glaciation, save in the conchoidal scoop on its eastern side and in the large landslip which (probably determined by Glacial steepening of grade) has slipped forward from its western side. Below the landslip a moraine occurs. Lower down, the valley is V-shaped, approximating to the U-shape. The upper part of the valley has local drift, but at the 800-foot contour the presence of Carboniferous boulders shows that the Rawthey Valley drift has been reached; and, owing to the Glacial widening of the Rawthey, the stream cuts through the deltoid drift-mass with increased grade. The ice of Hobdale was probably rendered nearly inert by the pressure of this Rawthey ice.

Between Hobdale and Pickering Gill, drift occurs on the west slopes of the Rawthey to a height of 1200 feet, plastered against a

truncated spur immediately south of the latter gill. A snow-slope 'moraine' crosses this gill high up.

We are now in the drainage of Cautley Beck, which Pickering Gill joins just before the former beck flows into the Rawthey. Cautley Beck occupies a wide U-shaped valley, the lower part of which is graded to the Rawthey. This beck presents an admirable example of a series of captures which, beginning in pre-Glacial time,

Fig. 5.—*The Cautley-Bowderdale diversions.*



[The broken lines indicate the former course of the drainage.]

have continued through Glacial time to the present day. The phenomena displayed are only explicable on the supposition that Bowderdale Beck (which flows northwards in a valley to be described later) once arose in two tributaries on each side of the plateau known as Great Dummacks, over 2150 feet high. The drainage

of both these tributaries and of another on the north, Swere Gill, is now into Cautley Beck. On the east side of Great Dummacks is the most marked rocky combe in the Howgill Fell tract, backed by Cautley Crags. The combe faces eastwards, but a large semi-circular recess at its southern end faces northwards, that is, in the direction of the beheaded Bowderdale. The stream from the west side of Great Dummacks, called Red Gill Beck, flows for a mile towards Bowderdale in a well-graded valley, the grade of which is continuous with that of Bowderdale. Shortly above Cautley Spout, however, it enters a gorge, and in the distance of about a sixth of a mile plunges in a series of continuous cascades down 600 feet of vertical height, forming the Spout or waterfall at the northern end of Cautley Crags.

The eastern wall of the southern recess of Cautley Crags is continued as a rocky spur, becoming truncated when 300 feet above the valley-bottom; and a corresponding truncated spur topped by a landslip occurs opposite on Yarlside, at a similar height.

This arrangement points to a former ridge right across the Cautley Valley, separating it from the former head of Bowderdale. This ridge must have been sawn through in pre-Glacial times, or in very early Glacial times: if in the latter, possibly as the result of a marginal Glacial overflow. The old spurs of this ridge have subsequently been truncated by the ice, which accumulated in the former head of Bowderdale: this has produced the great combe by glacial erosion. The ice has left a number of parallel moraine-mounds on the valley-bottom below the truncated spurs, extending for about half a mile down stream; and there is a shelf in the combe above the 1250-foot contour-line with terminal moraine upon it, left when the ice had shrunk to a corrie-glacier.

Red Gill Beck, before its plunge down Cautley Spout, has a wide valley; but the gentle slope on the south is cut away at the ridge by the rocky precipice of Cautley Crags. It is obvious to the observer on the spot that the recession of the combe by ice-erosion (with the accompanying landslip and frost-work above) has cut away the side of the valley nearer and nearer to the stream as it flowed north-westwards, until at last the whole of the side was removed, and the post-Glacial stream compelled to plunge down Cautley Spout, which it has carved into a waterworn gorge showing no trace of glaciation. Subsequently to this, the capture of Swere Gill has occurred. High Green Gill still drains into Bowderdale, but has built a delta almost to the col-level. This delta will soon become a 'corrom,' and will divert High Green Gill into Cautley Gill. The changes which have here occurred recall those of Carling Gill and Uldale Gill, although there are considerable differences in detail.

We now approach a tract of country, complex alike in the character of its river-captures and in its glaciation. It is drained on the south side by Backside Beck, Wandale Beck, and Sally Beck, the last-named here forming the boundary of the Howgill Fells and running practically along the Dent Fault.

From Yarlside on the west of Backside Beck a wide depression runs behind Wandale Hill to Adamthwaite and thence to Artlegarth Beck which drains to Ravenstonedale. This depression is essentially one valley, with its southern wall breached at two places by the narrow valleys of Backside Beck and Wandale Beck. That the Wandale breach was the earlier is indicated (1) by the lowering of the col between Backside Beck and Wandale Beck to a depth of 70 feet below that between Wandale and Artlegarthdale; (2) by the steeper grade of the Wandale Valley, the 1000-foot contour being far nearer to the head of Wandale than of Backside; and (3) by the recent diversion of Spengill from Wandale Beck into Backside Beck by a 'corrom,' showing that the tract where the delta occurs has been but recently dried by the beheading of the upper waters of the Backside stream, known as Stockless Gill. It will be seen from the plan (fig. 1, p. 590) and the section (Pl. XXXI, fig. 1), that Watley Gill, Stockless Gill, and Spen Gill now flowing into Backside Beck, and Adamthwaite Sike and Stoneley Gill, tributaries of Wandale Beck, all have their upper waters directed towards Artlegarthdale: the latter case is especially clear, as its upper part forms a hanging valley (as do the others in a less marked degree) and its waters flow at first northwards, but bend round through west to south to reach Wandale. The 'corrom' diversion of Spengill into Backside Beck has caused the latter to cut the well-known section in the Stockdale Shales while grading itself to its new conditions.

Turning now to the glaciation, two points in the physiography of the region must be noticed. First, the hills east of the Backside valley are much lower than those farther west; and, owing to the obliquity of Sally Beck and the Rawthey to Ravenstonedale, this part of the upland is much narrower than on the east. Secondly, the Fells of the high ground south of the Rawthey are nearer the Howgill Fells and higher than those farther west. There was, therefore, a great gathering-ground of ice in the amphitheatre in which the head waters of the Rawthey arise on the south between Baugh Fell (2216 feet), Swarth Fell (2235 feet), and Wild Boar Fell (2324 feet). Goodchild takes his ice-shedding line over this tract, and inserts on his map striæ running nearly due north over the col between Wandale and Artlegarthdale on the west side of Harter Fell. That ice carried material over in this direction is indicated by the presence of Carboniferous Limestone boulders on the west side of Sally Beck, above Low Spout Gill, at a height of about 1000 feet; also by the presence of boulders of Millstone Grit at the same height in Wandale near Adamthwaite, above the 1250-foot contour-line over the watershed in Gaisgill, the head of Artlegarthdale, and, lastly, on the 1200-foot line near the head of Wyegarthdale.

The Baugh Fell–Wild Boar Fell ice must have filled Wandale and Sally Beck, either leaving Harter Fell as a 'nunatak,' or at the time of maximum glaciation covering it, and going some way up the Backside Beck valley.

But Yarlside had its own ice. A large open combe occurs at its eastern side, with a terminal moraine below. This combe has receded by corrie-glacier erosion, cutting off the head of Little Randy Gill, a tributary of Bowderdale. The ice flowing from it, being prevented from flowing down the Backside Beck valley by the Baugh Fell ice, has flowed north-eastwards along the old beheaded Artlegarthdale, truncating the south-eastern slopes of Kensgriff, depositing drift on the col between Backside and Wandale, and carrying a train of boulders of Browgill Shales and red felsite from the upper part of Backside over the col to the Wandale Valley and onwards over the next col to Artlegarthdale. There, being prevented from going farther by the ice which had come from Wild Boar Fell by way of the north side of Harter Fell and filled the head of Ravenstonedale, the drift was dumped down.

There is one difficulty to notice. Below the hanging part of Stoneley Gill at the top of Wandale is a combe facing southwards. We would suggest that, as this lies athwart the general direction of the later ice, it may be due to a local corrie-glacier at an early stage of the Glacial Period.

We come now to the streams of the Ravenstonedale drainage, and shall follow them towards the west.

Ellergill Sike runs in a shallow valley. The stream is engaged in cutting through a deltoid mass of drift filling the valley-bottom, like those masses which occur in the gills to the north of Sedbergh and elsewhere.

North-east of Ellergill Farm is an old quarry by the high road, capped with drift and containing boulders of Carboniferous grit. In this tract of comparative lowland the general direction of the axes of the drumlins is east-north-east and west-south-west, whereas farther north-west their axes trend more nearly south-east and north-west. This points to the junction of the two ice-lobes (the one from the Lake District and the other from the Wild Boar and Baugh Fell region) in this part of the country.

The foreign drift in Gaisgill, the head of Artlegarthdale, has just been described. We may note the capture of the head waters of Wyegarthdale by this stream, with the production of the col (now occupied by drift) between Knoutsberry and The Knott on the north side of it. The former head of Wyegarthdale now forms the main tributary of Gaisgill, and enters that stream from the south immediately opposite the col. Its capture was due to the more rapid erosion of the Gaisgill stream, which runs over weak rocks along the shatter-belt. The lower part of Artlegarthdale is markedly U-shaped.

Thackthwaite Gill, west of Artlegarthdale, is a U-shaped valley with drift-filled bottom and presents no features of special interest. Wyegarthgill valley also has a deltoid mass of drift filling the valley-bottom; the head of this drift-mass lies some distance below the head of the valley.

The Dale Gill valley is wide and U-shaped, with a conchoidal scoop on its western side and a vegetation-clad combe at its head. West of this lie three very important valleys, namely Weasdale, Bowderdale, and Langdale, the last-named having also two important tributaries, Churn Gill and Uldale.

The eastern feeder of Weasdale, called Great Swindale, rises west of the top of Green Bell. The valley is V-shaped, but approximates below to the U-outline. It has a conchoidal scoop on its eastern side, with truncated spurs above and below. The bottom of the valley is occupied by alluvium nearly to the head. How far this alluvium is fluvio-glacial in origin has not been determined, though it is probable that, during the melting of the ice, the formation of alluvium in this and other valleys proceeded in a more rapid manner than has ever been the case subsequently.

At the head of Great Swindale we meet with a type of accumulation which forms a marked feature of the heads of many of the northward-flowing streams of the Howgill Fells: this requires some notice. The semicircular head of Great Swindale is occupied by loose material, which is being carved by rain-channels into buttressed ridges that are very characteristic. The general aspect of the accumulation at first sight suggests moraine, but a closer examination at once shows that it is not of morainic origin. It is composed of angular fragments of various sizes, and is clearly the result of weathering action only. Similar material occurs on the two sides of the valley some distance below the head, but is not there so thick. On the eastern side this material (continuous with that at the valley-head) covers the face of a conchoidal scoop produced by ice-erosion: hence it must be of post-Glacial origin, and cannot be due to pre-Glacial weathering. Its formation is still going on, although its destruction by occasional stream-action indicates that the formation is not now sufficiently rapid to replace the destroyed material, and the total amount is therefore dwindling: the main mass of it was probably formed by frost-action after the retreat of the ice.

The head of Weasdale proper is a large combe with similar subangular accumulation. Here the material is formed from the broken rock which fills the shatter-belt of the great fault. There is little sign of glaciation at the extreme head of the valley, the overlapping spurs of which have not been completely destroyed; but lower down the valley rapidly becomes U-shaped, and has truncated spurs. Between the points of entry of Great and Little Swindale its western side shows a good example of a well-truncated spur; and below the point of entry of Little Swindale the eastern side exhibits a similar phenomenon on the western face of High Knott. Little Swindale is largely choked by a drift-delta introduced from Dale Gill.

Little Beck, west of the lower part of Weasdale, is formed by the junction of two streams—Simongill Sike on the east, and Shawgill Sike on the west. The valley is short, and largely occupied

by drift. The head of Shawgill Sike is cut off, owing to the widening of Bowderdale by ice; and hence a marked col occurs between it and Bowderdale. Through this at one time there was a marginal overflow from the ice, and another smaller overflow drained somewhat farther north, but the water from this latter returned to Bowderdale at a lower point.

Bowderdale is the next important valley to the west. It is well graded below the col at which the capture by Cautley Gill has occurred. Below this col the valley for some distance is not appreciably glaciated, there having been no gathering-ground for the ice. About a mile north of the col it receives the waters of Hazel Gill from the west, and of Great and Little Randy Gills from the east. The valleys of these are V-shaped. Some drift occurs at the bottom of the united Randy Gill streams. Below the junction of these streams with Bowderdale the latter valley is markedly and suddenly affected by Glacial erosion, and becomes a U-shaped valley. It has a truncated spur on its eastern side between Watley and Leath Gills; and its lower part is nearly straight, with the spurs on each side of the valley well truncated. This feature is well shown by the change of slope when looking up the valley from the north side of the Lune near Ravenstonedale railway-station. We append a diagram of this, which illustrates the type of cross-section of the U-shaped valleys of the district.

Fig. 6.—*Outline of Bowderdale, seen from near Ravenstonedale railway-station.*

[The broken line indicates the pre-Glacial outline of the valley-slopes.]

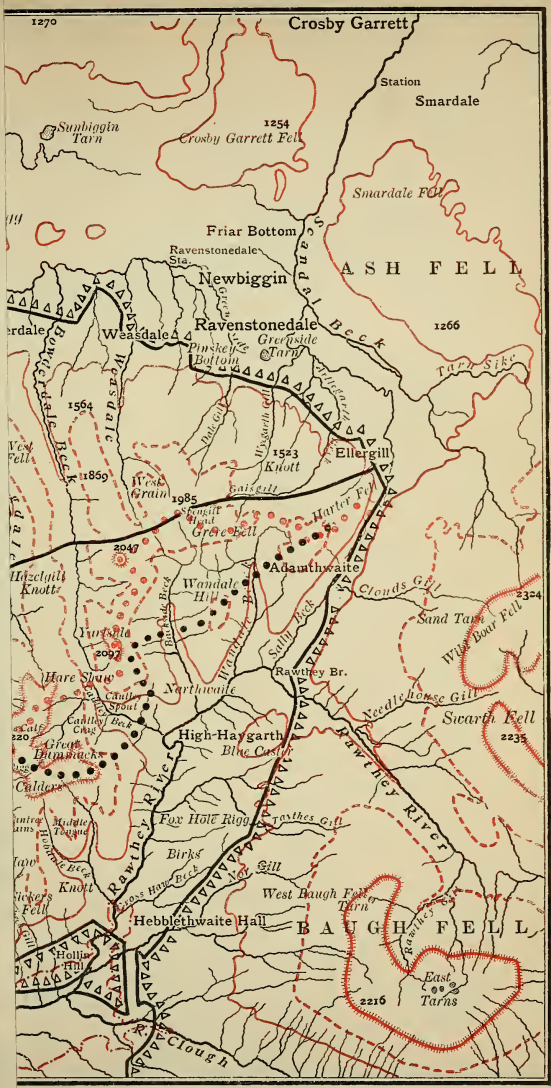
A wide expanse of moorland separates the lower part of Bowderdale from Langdale. Over this flow the two streams, Birk Gill on the east and Cote Gill Beck on the west. The tops of these valleys are cut off by the widening of Langdale by ice, and drift has passed over the cols thus produced and extends thickly down each of the valleys. Carboniferous boulders were found at Cote Gill Farm near the junction of the two streams, thus indicating that the Lake District ice occupied this more lowland region; but whether the drift at the head is that of the Lake District ice, or of ice coming over from Langdale, we did not discover.

The Langdale valley has three feeders:—Langdale Beck on the east, Churn Gill in the centre, and Uldale Gill on the west. Langdale Beck rises on the north side of The Calf, with three minor feeders of which the westernmost is beheaded by Longrigg Beck at Wind Scarth Wyke, as previously stated. The valleys

W. B. Brunskill, Photogr.

Bemrose, Collo., Derby.

THE HOWGILL FELLS, SEEN FROM ASH FELL.

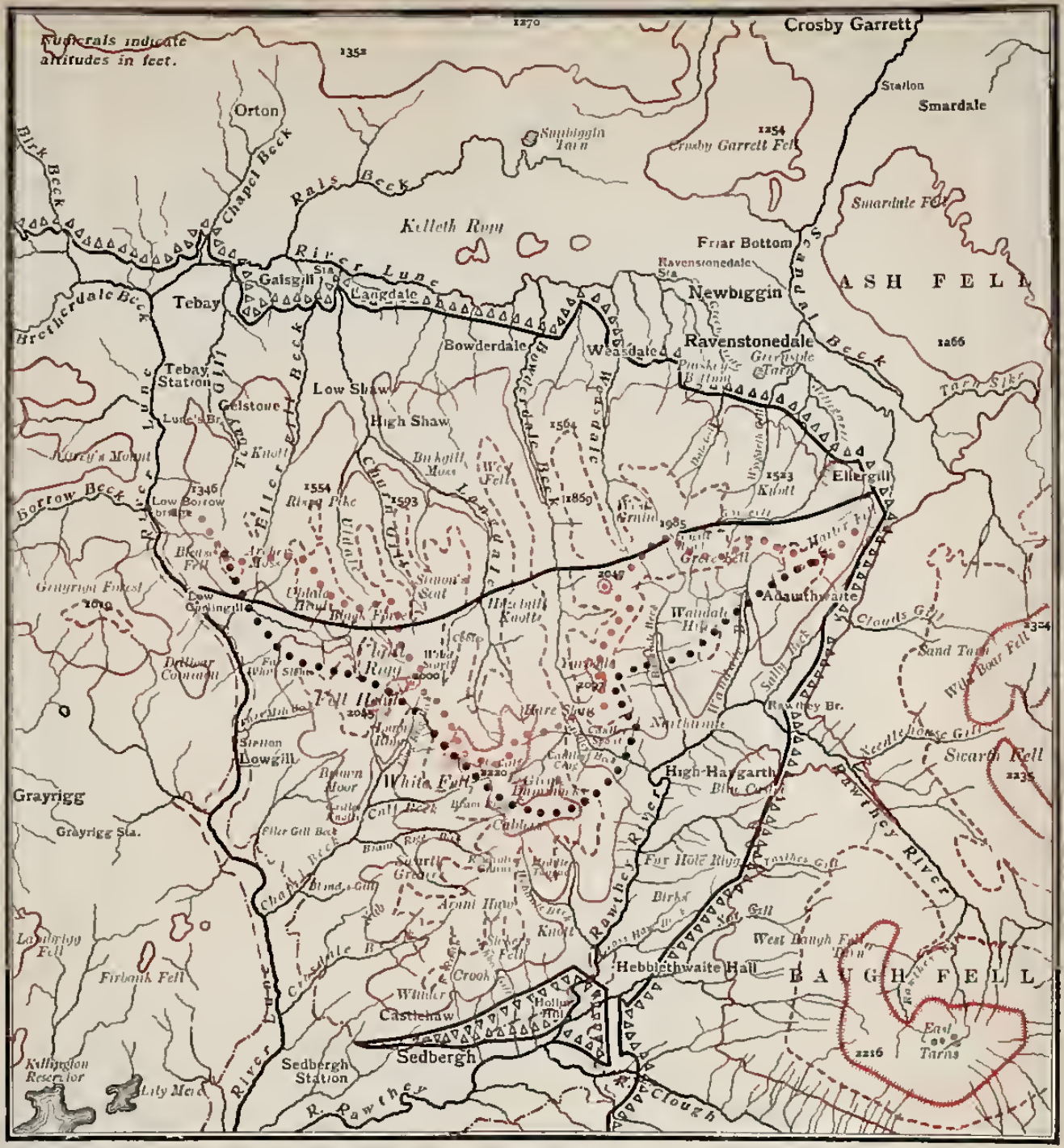


THE HOWGILL FELLS. (*Scale: 1 inch = 1½ miles.*)

= 1500 feet; = 1000 feet; = 500 feet

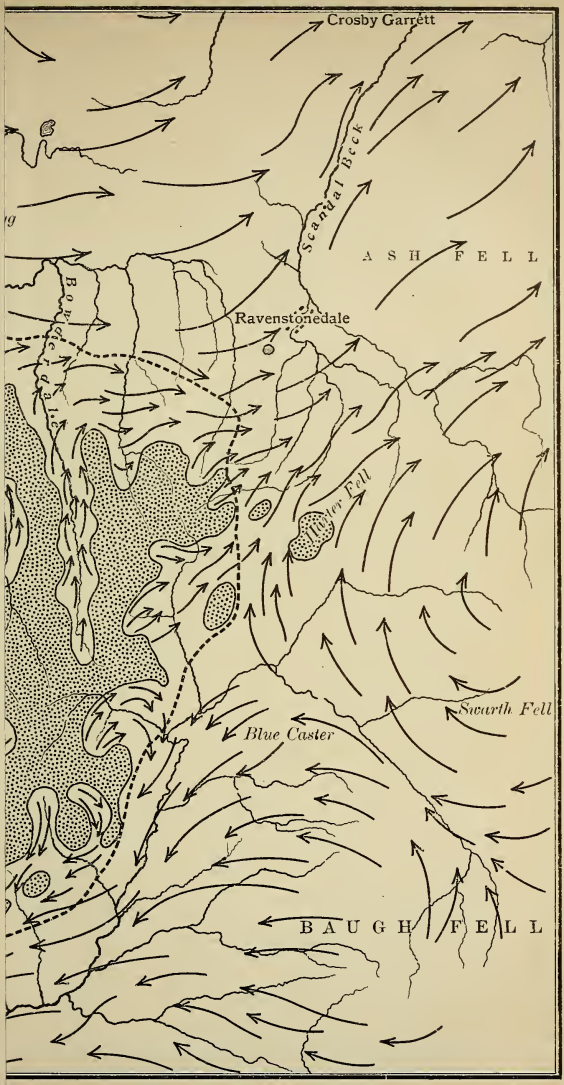
= The approximate line of the watershed which separated ill area, as determined by the original uplift.

oniferous from the older strata; the triangles have been placed upon which crosses the Silurian rocks of the Howgill area.]



THE RIVERS OF THE HOWGILL FELLS. (*Scale: 1 inch = 1½ miles.*)

[Contour-lines: ——— = 2000 feet; - - - - - = 1500 feet; ——— = 1000 feet; —·—·— = 500 feet
●●●●●●●● = Present watershed of the Howgill area; ●●●●●●●● = The approximate line of the watershed which separated the northward from the southward flowing streams of the Howgill area, as determined by the original uplift.
△△△△△△△ Line of outcrop separating the Carboniferous from the older strata; the triangles have been placed upon Carboniferous rocks ——— = Line of the shatter-belt which crosses the Silurian rocks of the Howgill area.]



F THE HOWGILL FELLS. *(Scale: 1 inch = 1½ miles.)*

oved. This has been inferred from a study of (1) the distribution of the erratic glacial sculpture; and (3) the alignment of the drumlins and other glacial deposits.

mit to which boulders of origin external to the Howgill Fells have been observed.

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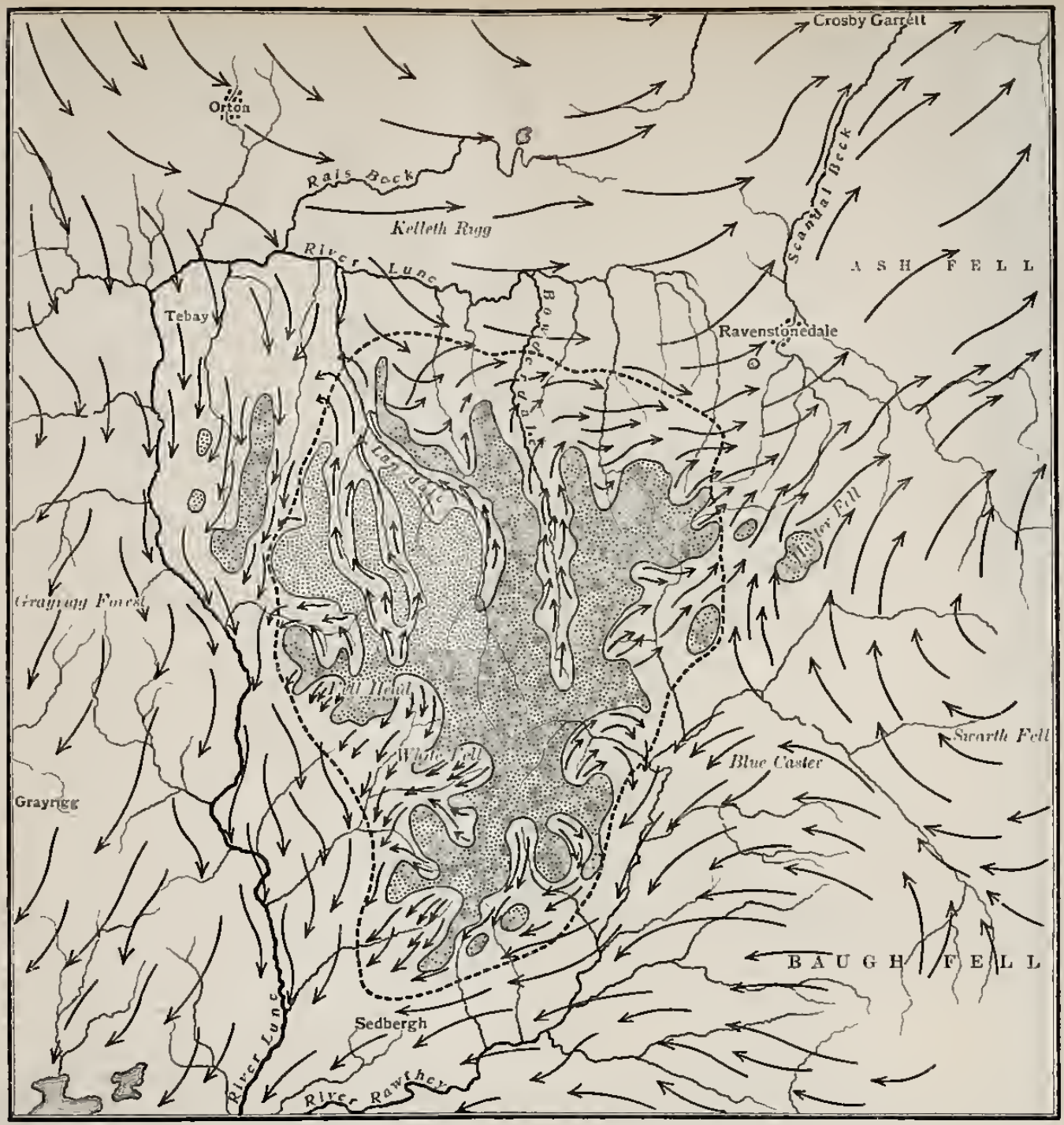


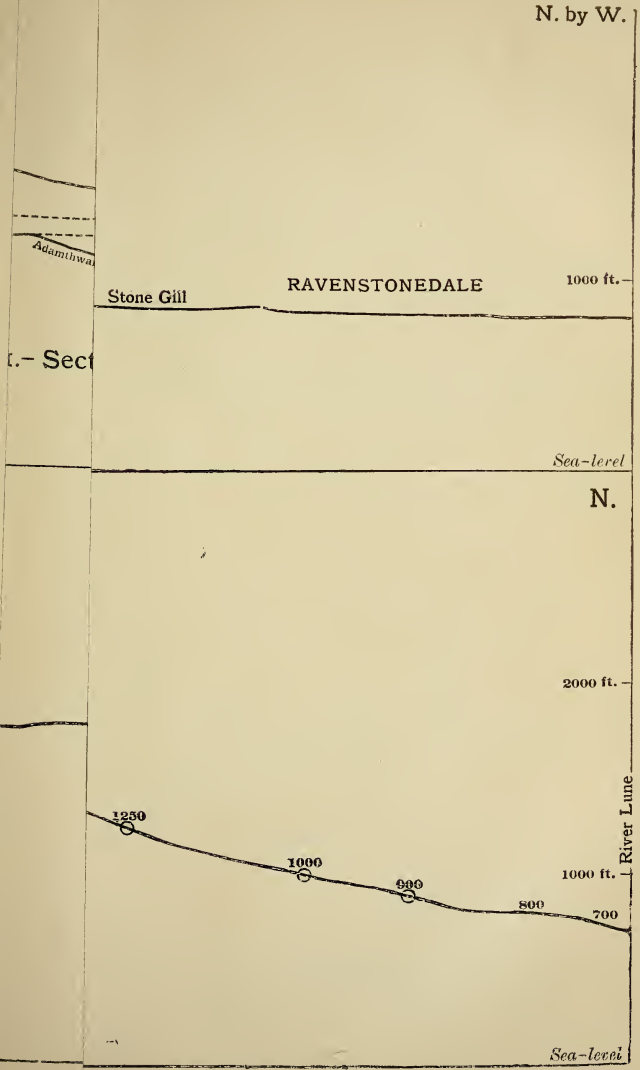
THE GLACIERS OF THE HOWGILL FELLS. *(Scale: 1 inch = 1½ miles.)*

[The arrows mark the direction in which the ice is supposed to have moved. This has been inferred from a study of (1) the distribution of the erratic boulders; (2) the character and localization of topographic forms due to glacial sculpture; and (3) the alignment of the drumlins and other glacial deposits.

The broken line surrounding the Howgill Fell area marks the upper limit to which boulders of origin external to the Howgill Fells have been observed.

The stippling indicates the area within the Howgill district upon which no evidences of glacial sculpture or erosion have been impressed.

The topography of the district is sufficiently indicated by the lines of the river-courses, which are the same as in the map of the rivers of the Howgill Fells (Pl. XXIX).]


N. by W.
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700
1000 ft.
Sea-level

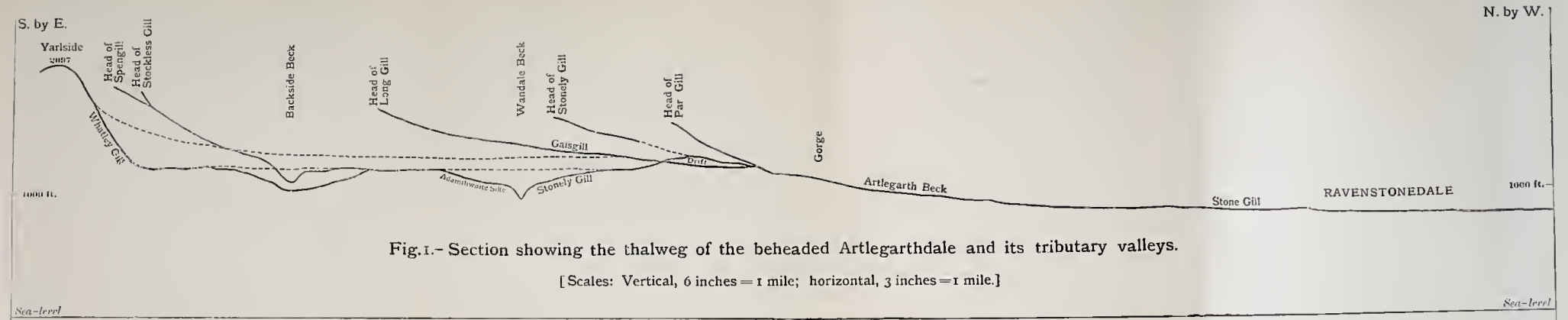

Fig.1.– Section showing the thalweg of the beheaded Artlegarthdale and its tributary valleys.

[Scales: Vertical, 6 inches = 1 mile; horizontal, 3 inches = 1 mile.]

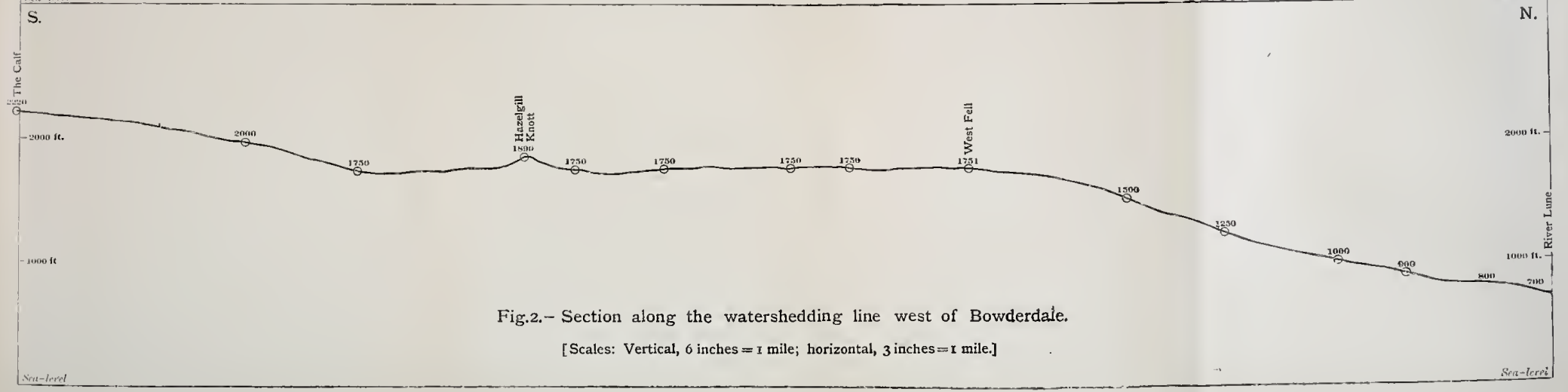

Fig.2.– Section along the watershedding line west of Bowderdale.

[Scales: Vertical, 6 inches = 1 mile; horizontal, 3 inches = 1 mile.]

of these little tributaries have small combes at their heads; and much angular drift of the type described in Great Swindale is laid bare, and is now being cleared out from them by the stream-action. Glacial action has produced little modification of the upper part of the Langdale valley, for the valley and all its feeders above the junction of West Grain are V-shaped. The head of West Grain contains the buttressed angular drift. Below the entrance of the West Grain stream, Langdale becomes suddenly and markedly U-shaped, with conchoidal scoops in the concavities and exhibiting well-truncated spurs. The bottom is occupied by alluvium or fluvio-glacial deposit.

Churn Gill also arises in a combe with much angular material at its head. It is U-shaped, but with an approach to the V-outline lower down.

Fig. 7.—*Uldale: a typical U-shaped valley.*

The capture of the head-waters of Uldale has already been considered. North of the 'corrom' at the watershed the valley is narrow, and a small moraine lies in the bottom immediately north of Blakethwaite Bottom. It then turns due north, and north of Uldale Head there is a combe, when the valley at once becomes modified by ice-erosion, and is a well-marked U-shaped valley all the way down to its junction with the Lune.

The occupation of the two remaining valleys, Ellergill and Tebay Gill, by foreign ice has already been mentioned.

Conclusions.

We may now sum up our results by stating that the Howgill Fells are a monoclinal block, formed of Silurian rocks which have been glaciated by their own ice. The erosive effects of the ice have been chiefly exerted in widening the valleys, by truncating the spurs and forming conchoidal scoops on the concave sides. The amount of deepening is small, as indicated by the slight difference of grade at the junctions of the tributaries and the main streams which is measured by only a few or at the most by tens of feet, the latter in the case of the junctions of the streams on the west side of the Fells with the River Lune. Accordingly, the hanging of the tributaries is insignificant. The great hanging valleys have been determined by the capture of the head-waters of the northward-flowing streams by the more steeply graded streams flowing southwards or south-westwards, although these captures have been partly aided by glacial action.

The rarity of roches moutonnées and ice-scratched surfaces is a noticeable feature, but it must be remembered that the places favourable for their preservation are chiefly masked by vegetation.

The comparatively feeble action of the ice may, of course, be largely due to its inability to obtain free outlet from the Fell country, owing to resistance and interference of the Lake District ice on the one hand and of the Wild Boar Fell and Baugh Fell ice on the other; and we have no desire to generalize, as to the action of ice in other regions, from our observations in this limited tract. We think, however, that our work may prove useful, as showing the varied effects of glaciation in a district of practically homogeneous rock, where there is every gradation from the ordinary valley-outlines of a water-eroded tract of moel type to those of a marked U-shape, such as are seen at Cautley where ice has exerted a very considerable influence.

EXPLANATION OF PLATES XXVIII–XXXI.

Plate XXVIII.

The Howgill Fells, seen from Ash Fell. The cultivated valley in the middle distance is Ravenstonedale. Notice the gentle northerly slope, increasing in steepness as it approaches the valley (see also Pl. XXXI, fig. 2) and the steep scarp facing southwards.

Plate XXIX.

Map of the rivers of the Howgill Fells, on the scale of a mile and a half to the inch.

Plate XXX.

Map of the glaciers of the Howgill Fells, on the scale of a mile and a half to the inch.

Plate XXXI.

Fig. 1. Section showing the thalweg of the beheaded Artlegarthdale and its tributary valleys.

2. Section along the watershedding line west of Bowderdale.

[Scales: vertical, 6 inches = 1 mile; horizontal, 3 inches = 1 mile.]